High Resolution Focusing Analysis and Inversion for Small Scatterer Detection

Final Report (SF-298): ONR Grant N00014-94-1-0530

submitted by

Norman Bleistein and Jack K. Cohen
Center for Wave Phenomena
Colorado School of Mines
Golden, CO 80401-1887

Submission date: May 25, 1996

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
SEATTLE REGIONAL OFFICE
1107 NE 45TH STREET, SUITE 350
SEATTLE WA 98105-4631

IN REPLY REFER TO:

4330
ONR 247
11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105
To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

INTRODUCTION

This is a final report on ONR Grant N00014-94-1-0530, entitled, High Resolution Focusing Analysis and Inversion for Small Scatterer Detection. The principal investigators Professor Norman Bleistein, Director, and Professor Jack K. Cohen, Center for Wave Phenomena, Colorado School of Mines. This report, in slightly different format was submitted to the monitor in November, 1994.

The long-term goal of this project is to develop software to invert acoustic data from a towed source/receiver array for simultaneous velocity analysis and imaging of small scale (7 to 15 cm) scatterers in the shallow ocean and seabed sediments.

The scientific or technological (S&T) objectives of the project are to develop the necessary theory for velocity analysis for this problem; characterize the typical shallow sea environment and seabed environment by one or two parameters and carry out the velocity analysis for those two parameters. Current software allows us to process single lines of data

We have developed methods to invert single lines of data to produce a reflector map of the interior of the Earth—either (i) single-shot/multi-receiver data or (ii) multi-shot/multi-receiver data in fixed offset mode. Multi-shot data in (i) or multi-offset data in (ii) is used to determine spatial variations of signal velocity by requiring that a particular reflection image be located at the same position for inversion from all shots (i) or from all offsets (ii). By choosing reflection "images" at progressively deeper locations, we recursively develop variable signal velocity functions. Our current computer codes implement this method assuming a single line survey of 3-D point sources in a medium with two-dimensional propagation speed variation. The theory for 3-D application to an areal source/receiver survey is already in place.

APPROACH

Our method produces an output at each point as an integral (sum) over all source receiver pairs in the survey. Data is picked out at the traveltime consistent with propagation from source to output point to receiver in some model of background propagation. The reflector image is produced as a continuum of bandlimited delta functions that peak on the reflectors. The unique feature of our method is a weighting of each contribution to this sum; this weighting is derived from an inversion theory. The theory predicts that the peak amplitude of the output is the angularly dependent reflection coefficient for the specular source/receiver pair. A second processing algorithm, differing from the first by only one factor, allows identification of the incidence angle for that specular reflection coefficient. Processing "many" offsets provides multiple reflection coefficient/incidence angle pairs for each position, from which one can estimate the change in medium parameters across the reflecting surface(s). Before this detail of processing, multi-offset imaging provides a means of correcting the background velocity, since incorrect background velocities produce reflector maps that do not agree. We have a formalism that uses the disagreement between the images to update the background velocity; this is velocity analysis.

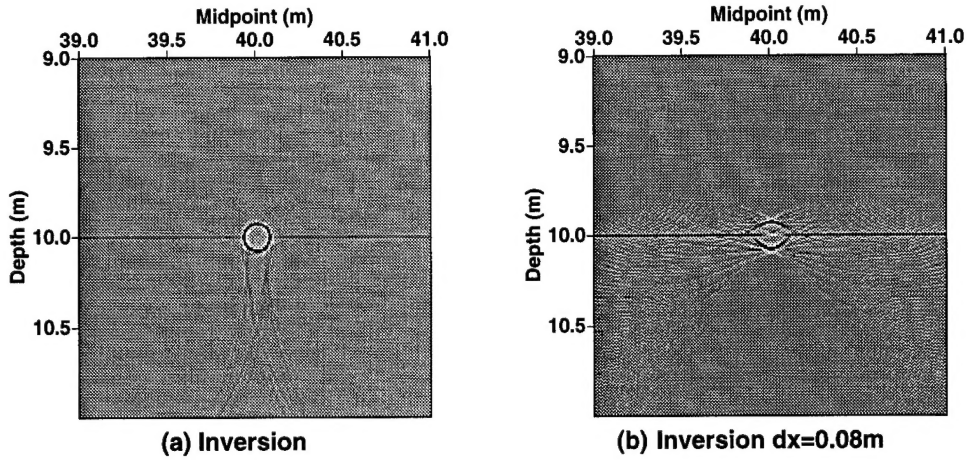

FIG. 1. (a) Benchmark inversion of synthetic data modeling a shallow water acoustic survey at indicated sampling rates in space and time. (b) Degraded image produced when the spatial separation of receivers is increased from 4cm to 8cm.

PROGRESS TO DATE

We have adapted our current 2.5-D inversion algorithm, derived for seismic exploration scales, to the length and time scales of the problem of interest here. In particular, we produced inversion output for numerically generated data for the following model. A 7.5cm radius cylindrical scatterer sits on a flat seabed at 10m depth. A towed array on the surface records reflection data from a 20-80Khz impulsive source set off at 5m intervals. The array is 10m long starting 2m behind the source. The receivers on the array are 4cm apart. Data are sampled at .005msec. Data from fourteen shots are generated, producing a data array covering 80m of the upper surface (14X5 + 10).

Figure 1a is our benchmark example of a scatterer of circular cross section imaged by our method. In Xu and Bleistein [1994], we show how the image degrades when (i) the bandwidth of the source is decreased or (ii) the temporal sample rate is decreased or (iii) the spatial sample rate of the receivers is decreased. The degradation of output in any of the above situations suggests that our parameter bounds are "tight." Figure 1b is an example from Xu and Bleistein [1994], demonstrating the degradation of the image when the spatial separation of the receivers is increased by a factor of 2. More examples appear in the reference.

We have also demonstrated simultaneous velocity analysis and scatterer detection. Assuming a single scatterer in a homogeneous host medium and data gathered on two survey lines, we use farfield traveltime analysis to simultaneously determine the velocity in the host medium and the location of the scatterer. Our current methodology is capable of more sophisticated velocity analysis than in this example.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 24, 1996	Final Report- expired 15 Nov 1994

4. TITLE AND SUBTITLE
High resolution focusing analysis and inversion for small scatterer detection

5. FUNDING NUMBERS
246:ymm
N00014-94-1-0530

6. AUTHOR(S)
Norman Bleistein & Jack K. Cohen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Center for Wave Phenomena
Colorado School of Mines
Golden, CO 80401

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Not classified

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report, in slightly different format was submitted to the monitor November, 1994.

We have adapted our current inversion algorithm to the length and time scales of the seamine detection problem. We produced inversion output for numerically generated data for a model that fits the detection parameters, thereby demonstrating the feasibility of this type of survey and processing for the seamine detection problem.

14. SUBJECT TERMS
inversion, seamine detection, towed array, reflector map

15. NUMBER OF PAGES
2

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	none